

EFFICACY OF COMPRESSION GARMENTS TO SIMULATE FLUID SHIFTS DURING LUNAR BEDREST

Abstract #921



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Objective

Evaluate the effectiveness of JOBST® compression stockings for fluid redistribution in the lunar bed rest analog based on Digital Astronaut computer model predictions.

Background

NASA's future goals include missions to the moon which will require extended exposure to the lunar gravity (1/6 Earth gravity) environment. To prepare for these missions, physiological adaptations in various systems must be resolved. We have used bed rest at a 10° head-up tilt to simulate lunar gravity.

Plasma volume (PV) loss may cause some of the cardiovascular adaptations which occur during space flight so PV is measured in the in bed rest analog to evaluate fluid loss^{1,2}. Plasma volume varies from individual to individual so plasma volume index (PVI) is used to determine the magnitude and time course of fluid shifts and cardiovascular adaptation to 1/6 g. PVI is calculated by plasma volume divided by body surface area.

The Digital Astronaut³, a computer simulation tool, predicts a 6% PV loss during an extended simulated lunar mission for a male with a body surface area of 1.95 m². This is a pre-bed rest PVI of 1.54 L/m².

Simple geometry calculations suggest that 10° head-up tilt is most useful for simulated measurement of deconditioning in bone and muscle; however, 2° head-up tilt may best imitate cardiovascular fluid shifts. In order to reconcile these different models, compression stockings must be used in the ten degree paradigm to better approximate expected cardiovascular fluid changes.

Methods

Three days prior to the first day of testing, subjects (n = 13) were admitted to the bed rest unit and placed on a controlled diet. PV was measured by the carbon monoxide re-breathing technique⁴. Baseline PV was measured at 6pm one day prior to beginning bed rest (BR-1). Subjects remained at a 10° head-up position for 6 days followed by a second PV measurement at 6pm (BR+6). Knee-high (n = 2) and thigh-high (n = 11) JOBST® stockings (Rutherford College, NC) were worn from 6am to 10pm. Efficacy of the stockings was determined by the average PVI (Plasma Volume/Body Surface Area) which most closely approximated the Digital Astronaut model prediction. A two-sample student t-test assuming equal variances was used to determine the difference between the two stocking types.

Results

Overall, PVI is decreased by $13.35\% \pm 3.14$ (mean \pm SE) during head-up bed rest. The knee-high stockings (n = 2) resulted in a PVI decrease of $3.92\% \pm 11.15$ while the thigh-high stockings decreased plasma volume by $15.07\% \pm 3.13$. There was not a significant difference between the two stocking types ($p = 0.21$).



Figure 1. Thigh-high compression stockings used in the Lunar Analog Feasibility Study. Stockings alone on left. Stockings worn by a subject on right.

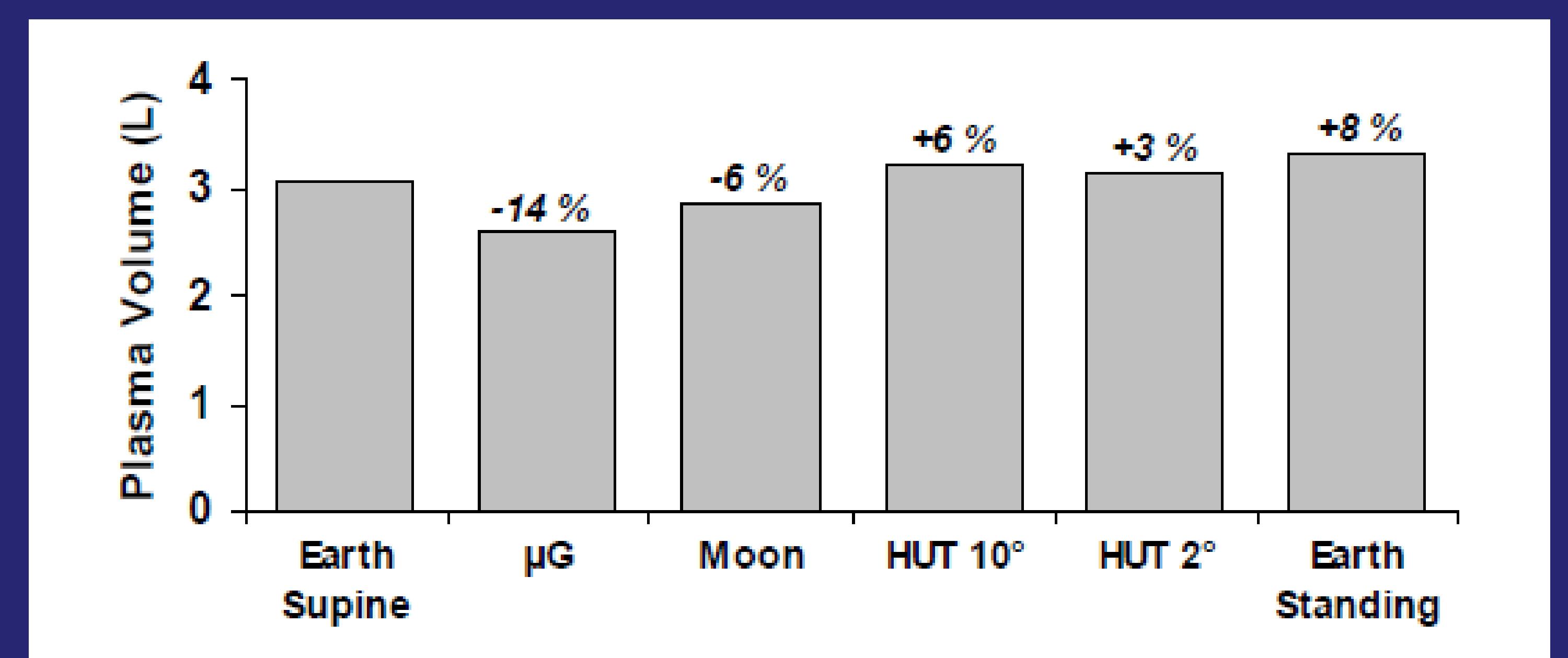


Figure 2. Computer systems analysis predictions for plasma volume in a variety of gravitational fields, including head-up tilt (HUT) bed rest models. None of the head-up tilt models accurately reproduce lunar gravity plasma volume losses.

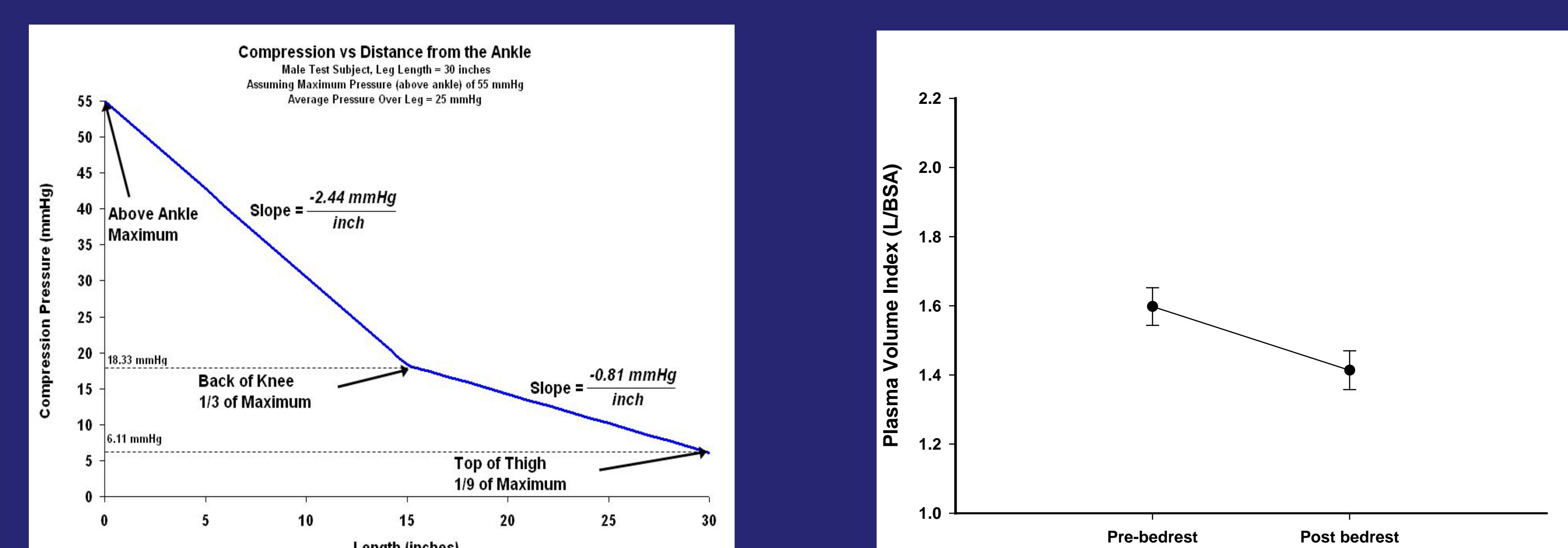


Figure 3. JOBST Stocking compression profile

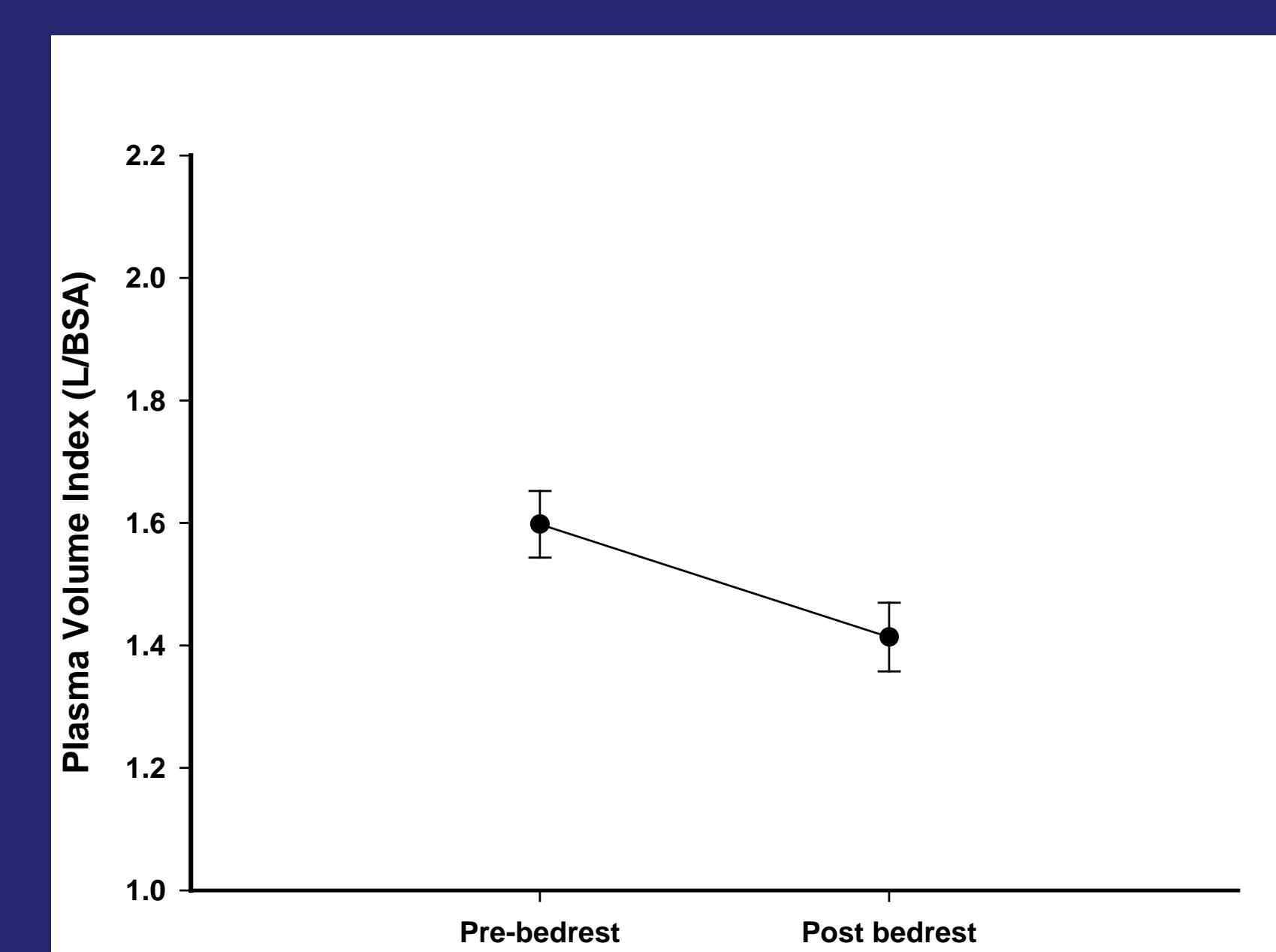


Figure 4. Plasma volume index change from pre-bed rest to post bed rest (n = 13, $-13.35\% \pm 3.14$).

Conclusions

PVI losses confirm the value of this model of lunar gravity for fluid shifts predicted by the Digital Astronaut. There were no statistical differences between stocking types. Subject comfort and compliance were enhanced by use of the knee-high stockings; therefore, knee-high stockings will be used in further lunar bed rest studies. Larger amounts of fluid were lost than expected which may have been due to the amount of compression; the stockings were originally designed for ambulatory patients needing compression to aid in cardiovascular circulation dysfunction. Additionally, diet was only controlled for three days prior to bed rest which may have contributed to differences from predicted values.

Future Studies

These measurements were a part of the Lunar Analog Feasibility Study (LAFS), therefore, a limited number of subjects have been evaluated. Additional subjects in bed rest over longer durations will provide a better perspective of fluid shifting and associated plasma volume loss in simulated lunar gravity. The compression of the stockings will be decreased to further emulate the expected 6% plasma volume loss.

There is no substitute for actual spaceflight data. It will be ideal to obtain lunar gravity plasma volume data from spaceflight studies when NASA returns astronauts to the moon after 2020. The lunar bed rest model will not be fully validated until 2025 or 2030 as it is unlikely lunar missions will increase to 60 days soon after the first few lunar landings.

References

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